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Piers 24 & 25 Marine Sediment Remediation Challenges and Solutions, Tacoma, Washington

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ABSTRACT: The Port of Tacoma completed a multiphase marine construction project between October 2007 and February 2008 to remediate approximately 3 acres (1.21 hectares) of contaminated intertidal and subtidal sediments along rocky marine shoreline areas. The sediments were near the mouth of the Hylebos Waterway and in a portion of Commencement Bay in Tacoma, Washington. The work was completed as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead project. Sediments were contaminated with metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) associated with historical shipyard operation, vessel repair, and related marine activities. Remediation included removal of fused metallic debris piles from intertidal and subtidal embankment slopes, followed by difficult under-pier capping, subtidal dredging, and embankment excavation. Construction was complicated by limited access to under-pier work areas, winter tidal conditions, and embankment stability concerns. Construction also required coordination with concurrent pier repair and piling replacement work during much of the project. Adaptive engineering and construction approaches succeeded in overcoming these challenges, leading to the achievement of project regulatory and design goals. The Piers 24 and 25 remediation project demonstrated the effectiveness of practical and adaptive construction methods in difficult nearshore marine environments. The work has transitioned to the post-construction performance monitoring phase.

INTRODUCTION

The Port of Tacoma completed the Piers 24 and 25 Embankment Remediation Project in 2007 and 2008 as one of the last sediment cleanup actions in the Commencement Bay Nearshore/Tideflats Superfund Site (Figure 1). Remediation followed several stages of site characterization and remedial design beginning in the mid-1990s, leading to the United States Environmental Protection Agency's (EPA's) conditional approval of the final design documents in 2007. Although relatively small in size, the site location in the Mouth of the Hylebos Problem Area and access constraints presented significant design and logistical challenges for sediment capping and excavation. Water quality issues during construction and potential recontamination of previously dredged areas of the Hylebos Waterway and Commencement Bay posed additional concerns.

Site Description and Historical Summary. The Piers 24 and 25 Embankment Remediation Project area is located near the northeast corner of the peninsula between the Hylebos and Blair Waterways as shown on Figure 1. The total shoreline embankment length for remediation was approximately 1,200 feet (366 meters [m]). The project area

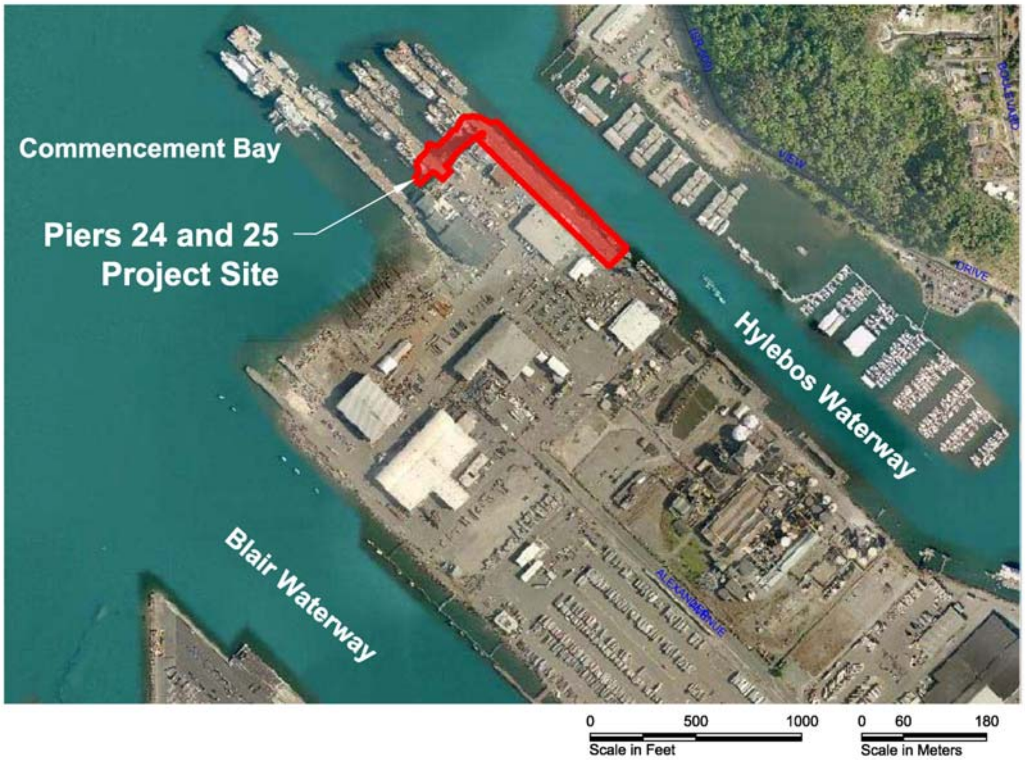

FIGURE 1. Piers 24 and 25 project site and vicinity, Tacoma, Washington.

includes intertidal and subtidal embankment areas with slopes approaching an angle of 2 horizontal to 1 vertical (2H:1V) and local steeper sections. Intertidal portions of the slopes were historically covered with heavy riprap armor to stabilize wooden bulkheads supporting the piers and adjacent uplands (Figure 2). The lower portions of the embankment slopes consist of sand and silt cut slopes extending to elevations of about –30 feet (–9.1 m) mean lower low water (MLLW). The piers are supported by thousands of wooden pilings in bents spaced roughly 10 feet (3 m) apart.

The Port currently leases Piers 24 and 25 and associated buildings and yard areas for vessel staging, loading, servicing, and a support facility for a commercial seafood fishing fleet. The project site area and adjacent uplands were historically used for shipyard operations, vessel repair, vessel retrofitting/salvaging, metal fabrication, and other activities. Several large debris piles consisting of fused metal, welding wastes, brick, and other construction debris from historical disposal activities were present at several locations on the embankment slopes.

REMEDIATION ELEMENTS AND CONSTRUCTION METHODS

Working closely with EPA, the U.S. Army Corps of Engineers (USACE), and the Washington State Department of Ecology, key design concepts for capping and other remedial construction activities were developed and further refined during construction. Primary remediation elements for the project included (1) removing the metallic debris piles from the embankment slopes; (2) placing sand, rock armor, and shotcrete capping materials to chemically and physically contain contaminated embankment sediments; and

(3) excavating sediments with PCBs and other contaminants from upper embankment "hot spot" areas. Construction challenges and solutions for each of these elements are summarized below. Subtidal dredging was also required in two areas with elevated arsenic concentrations, but did not prove to be particularly problematic using conventional clamshell and excavator bucket dredging methods.

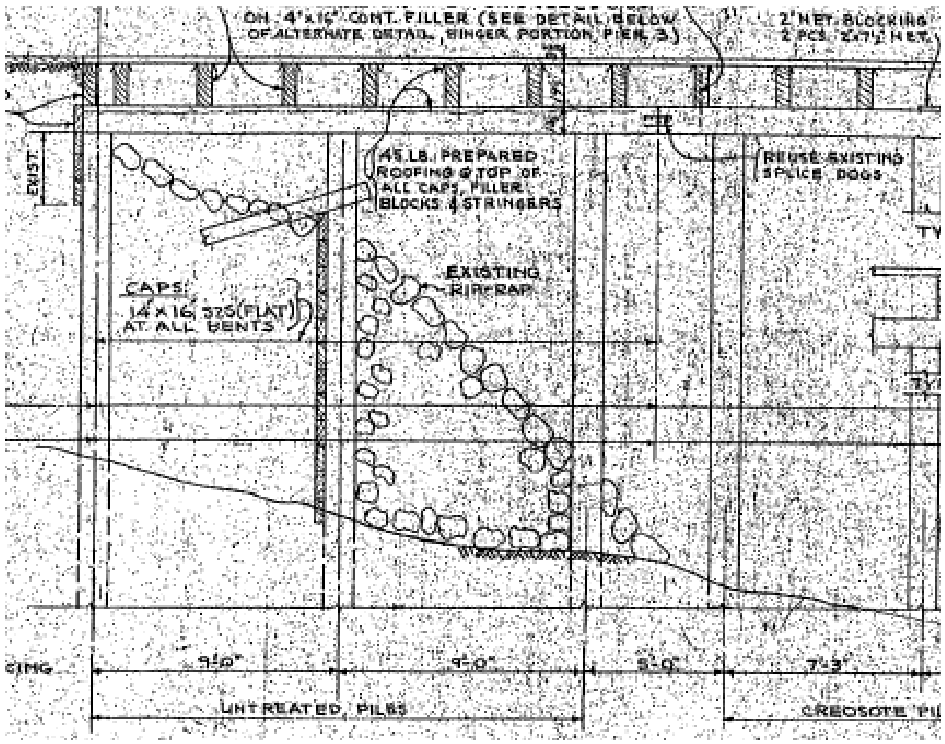

FIGURE 2. Historical cross section drawing showing under-pier construction with bulkhead structures and riprap slope support. ***Source: Port of Tacoma.***

Metallic-Debris Pile Removal. Metallic-debris piles consisting of more than 500 tons of amalgamated and indurated materials represented recognized contaminant sources in the aquatic environment. The presence of the debris piles also impeded embankment capping in the intertidal zone. Debris pile removal work was challenged by limited space in under-pier areas for staging the equipment and personnel needed to break the piles apart and transfer excavated material topside. Cross contamination of the nearshore environment and water quality impacts from potential loss of debris material during removal were additional concerns.

Debris pile removal proceeded by removing enough pier decking to maneuver machine-mounted impact breakers through the openings and break apart the debris piles remotely. In other areas, where access allowed and where larger equipment was not needed, personnel used jack hammers to manually break up debris piles. Loosened debris fragments were then carefully lifted through the deck openings in buckets or via clamshell excavator (Figure 3). To manage the excavation and minimize downslope loss of material to marine waters, much of the debris removal was planned during low tide periods. Containment curtains, planks and other barricades were braced between downslope pilings as a relatively simple method to further isolate the work areas.

Construction methods used for debris pile removal proved effective for excavating and extracting debris and leaving a relatively clean, even surface for subsequent slope capping. However, at one location between the site piers, deeper excavation to the original tideflat surface was necessary to capture fragmented debris that had sifted downward through underlying riprap. A long-reach excavator staged on the upland bank was used during low tide periods to complete excavation and backfilling. Although somewhat labor intensive, using the debris breakup and removal methods eliminated the need for more elaborate excavation and containment measures, particularly when accomplished in the dry.

FIGURE 3. Metallic debris pile removal challenges.

Sand Cap and Rock Armor Placement. Design efforts for embankment capping followed established EPA and USACE protocols (EPA 1998 and USACE 1998) to accomplish several objectives:

- Physical isolation of contaminated sediments
- Physical stabilization of contaminated sediments, and prevention of resuspension and transport from wave erosion and propeller scour
- Reduction of groundwater contaminant transport to prevent surface sediment recontamination, adverse biological effects, and exceedances of marine water quality criteria

Several capping methods and material types were used to achieve these objectives and stabilize capping sections. Capping extended from the top of the bank at about elevation 17 feet (4.6 to 5.2 m) MLLW, to the toe of the slope at about elevation –30 feet (–9.1 m). Imported sand cap material and overlying 1½-inch-minus [3.8 centimeter (cm)] angular surface armor rock were successfully placed as capping materials along the subtidal portions of the embankment (Figure 4). The minimum sand cap thickness was established as 2 feet (0.61 m), with minimum rock armor thickness of 1 foot (0.30 m). To impart greater stability and avoid downslope loss of capping materials during and following placement, angular crushed rock rather than gravel aggregate was incorporated into the sand cap mix at 50 percent by weight. The resulting mix formed a stable sand cap on 2H:1V slopes while retaining sufficient sand content for contaminant containment. Predicted contaminant breakthrough times for most chemical constituents using a conservative analytical model were in excess of 25 years.

Design and performance-based specification requirements for sand cap and rock armor capping were developed to provide a flexible approach during construction. The remediation contractor, Bergerson Construction (Vancouver, Washington), further improved on the general design concepts by using conveyor and tremie equipment staged from the pier decks (Figure 4). Using this method, capping material was transferred to the point of placement on the embankment slopes, aided by personnel stationed on small floating rafts to guide the placement end of the tremie tube. This placement method provided a high degree of accuracy, with minimal separation of gravel from the sand cap mix, and little persistent water column turbidity. Increasing the angular gravel content of the sand cap also allowed the contractor more freedom of placement by eliminating the need to build the cap from the bottom of the slope upward. Typical placement volumes of 200 to 400 cubic yards (yd^3) (153 to 306 m^3) per shift were achieved. Other attempted placement methods involved conveyor delivery of capping materials from a barge, but this was hampered by the maneuverability of the conveyor boom, and limited storage space for capping material on the barge.

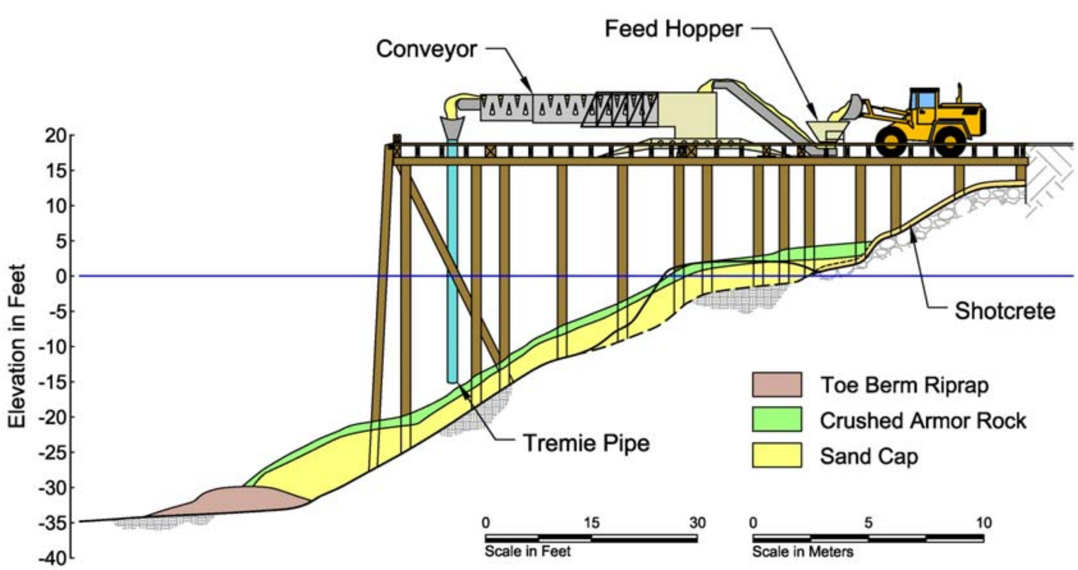

FIGURE 4. Under-pier embankment capping section showing sand cap and armor rock placement method.

Shotcrete Cap Placement. Contaminated sediment in riprap cracks and crevices along the upper embankment presented further capping challenges that were addressed by applying a high-strength, polymer fiber-reinforced shotcrete mix to encapsulate the slope. Contaminated particulate material was tightly packed into the riprap interstices by decades of wave action and would have been inherently difficult to remediate using other methods. Discussions with EPA, USACE, and other parties helped inform the shotcrete basis of design to develop key performance objectives:

- Provide a durable, long-term physical and chemical containment barrier
- Further immobilize and seal particulate material within the crevices and pockets of the existing riprap slope
- Direct seepage water into the downslope sand cap using an underdrain
- Minimize future maintenance and repair

Trial shotcrete mixes were initially evaluated in a test panel area along the Pier 25 embankment with adjustments made to the proportions of microsilica and cement, fiber type and dosage, and air entrainment admixtures. Initial test panels used an on-site, wet-mix batching process, whereas subsequent production batches were dry-mixed off site with an admixture to retard setting. On-site batching could be more easily controlled to match placement rates, but was susceptible to clogging if fiber content was not closely monitored. Off-site batching produced consistent mix proportions but required careful scheduling to accommodate placement rates.

Shotcrete was applied in the dry during night time low tide periods using a high-pressure spray nozzle. A team of three to five workers controlled the delivery and application process. Shotcrete was placed to form a uniform, 4- to 8-inch-thick (10.2 to 20.4 cm) layer to fill existing riprap crevices and pockets, with thickness verified by preset grade stakes. The batching and application methods provided sufficient time for the shotcrete to solidify and prevent washout of the material into the water column with the incoming tide. Observed shotcrete setting times were typically on the order of 90 minutes, at which point the material was firm to the touch. Typical shotcrete placement rates of 50 to 60 yd^3 (38 to 46 m^3) per shift were achieved, with test sample compressive strengths exceeding the 28-day quality assurance threshold of 8,000 pounds per square inch (55 megapascals).

Groundwater and water seepage beneath the cap presented a concern for potential contaminant transport and hydrostatic pressure buildup with changing tidal conditions. As a precautionary measure, the contractor installed a 3-inch (7.62 cm) diameter, perforated acrylonitrile butadiene styrene (ABS) underdrain piping system to route seepage water downslope into the sand cap. The drainage pipes were protected with a factory-installed geotextile material to reduce potential for intrusion of shotcrete and underlying particulate material that could clog the pipes. The pipes were connected to ABS diffuser/lateral spreaders to distribute the discharge within the sand cap.

PCB Hot Spot Embankment Slope Excavation. EPA's conditional approval of the 2007 final remedial design required supplemental sediment sampling and chemical testing along the upper embankment beneath Pier 25 to better determine the extent of elevated PCB concentrations. Subsequent rounds of sample collection and testing delineated a PCB hot spot area with concentrations triggering Toxic Substance Control Act (TSCA) regulatory requirements. The historical PCB source could not be identified but was likely related to industrial operations supporting previous shipyard activities. The presence of sandy and silty sediments packed into crevices and pockets in riprap armoring the embankment made sampling difficult and complicated the process of defining and excavating the hot spot.

TSCA-levels of PCBs required removal using long-reach excavators staged on the overlying Pier 25 deck and adjoining bank area. As during removal of the metallic debris piles, the contractor removed a section of the pier deck to gain access for equipment and personnel in the PCB hot spot area. Four successive excavation efforts were necessary to remove riprap and expose pockets of PCB-contaminated sediments for excavation. Steep slopes, the presence of riprap, and logistical limitations for conducting the work in the dry during nighttime low tide periods further complicated excavation. The hot spot excavation area was progressively deepened to remove contaminated material and transfer spoils through the pier decking for off-site disposal. Digging became more difficult with depth as PCB concentrations increased and tidal work windows became shorter. The work culminated in final low-tide excavation in January 2008 through shallow water at an elevation of nearly –4 feet (–1.2 m) MLLW. The general increase in PCB concentrations with depth suggested downward migration and accumulation of contaminated source material and sediments near the original tide flat surface. Backfilling with sand cap material commenced immediately following excavation to restore the slope and address stability concerns.

Although difficult and costly, the PCB hot spot excavation relied on conventional construction methods and equipment. This excavation approach was cautiously implemented during low-tide periods without adversely affecting water quality or structural stability of the embankment.

CONCLUSIONS AND APPLICABILITY TO SIMILAR SITES

The site setting of the Piers 24 and 25 Embankment Remediation Project presented a number of challenges for addressing project remedial action objectives. Chief among these was the challenge of placing capping materials on relatively steep nearshore slopes and developing engineering and quality assurance measures to ensure adequate cap thickness and stability. Access constraints to under-pier areas, the presence of pilings, and the need to complete much of the work during late fall and winter night time low tides further necessitated somewhat innovative approaches to contracting and construction. The approach to capping and other remedial actions summarized in this paper represents a useful reference point for design and construction considerations on nearshore remediation projects with similar site features and cleanup objectives.

Related conclusions and recommendations follow based on experience from the current project and other nearshore remediation efforts.

Work During Low-Tide Periods. As demonstrated by the Piers 24 and 25 Embankment Remediation Project, the effectiveness of intertidal debris removal, excavation, and other construction activities can be enhanced by working in the dry to better manage the work and control potential water quality issues. However, contractual requirements to limit work during low-tide periods must be carefully balanced against potential production inefficiencies introduced by such constraints. Related cost/benefits should be evaluated during design to determine if restricting work to low-tide periods can effectively achieve project remediation objectives.

In-Water Work Windows and Contractor Incentives. Construction scheduling for in-water projects has become increasingly restrictive in many parts of the United States because of concerns over potential biological resource impacts. Contract requirements must provide a reasonable time frame to complete the work, while creating an incentive for the contractor to schedule the work as efficiently as possible. As for many projects, the Piers 24 and 25 work specifications were developed with performance-based objectives to preserve flexibility for the contractor to develop appropriate construction means and methods based on performance requirements and cost considerations.

Specifications for projects with limited work windows could be enhanced to include provisions or incentives for production or performance milestones tied to specific dates. This would help to encourage more rigorous contractor planning and build in time contingencies to deal with additional challenges or unexpected conditions that might otherwise jeopardize completion of the work within the overall work window. Ideally, projects with multiple work activities, construction phasing challenges, or using innovative applications such as the placement methods used for the current project should be planned to begin at the beginning of the in-water work window. This would provide more contingency, if needed, to deal with unexpected field conditions, delays, or other construction scheduling issues.

ACKNOWLEDGMENTS

The Port of Tacoma and Hart Crowser wish to thank the Battelle Memorial Institute, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, Washington State Department of Ecology, Bergerson Construction (Prime Contractor), and Berger/ABAM (design engineering assistance).

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United States Army Corps of Engineers 1998. *Guidance for Subaqueous Dredged Material Capping.* Technical Report DOER-1. June 1998.

Piers 24 & 25 Sediment Remediation Project

Tacoma, Washington

Lessons in Underpier Capping

Bill Evans, Port of Tacoma

Rick Moore, Hart Crowser Project Manager

Battelle Sixth International Conference

On Remediation of Contaminated Sediments

February 9, 2011

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PORT of TACOMA U.S.A.

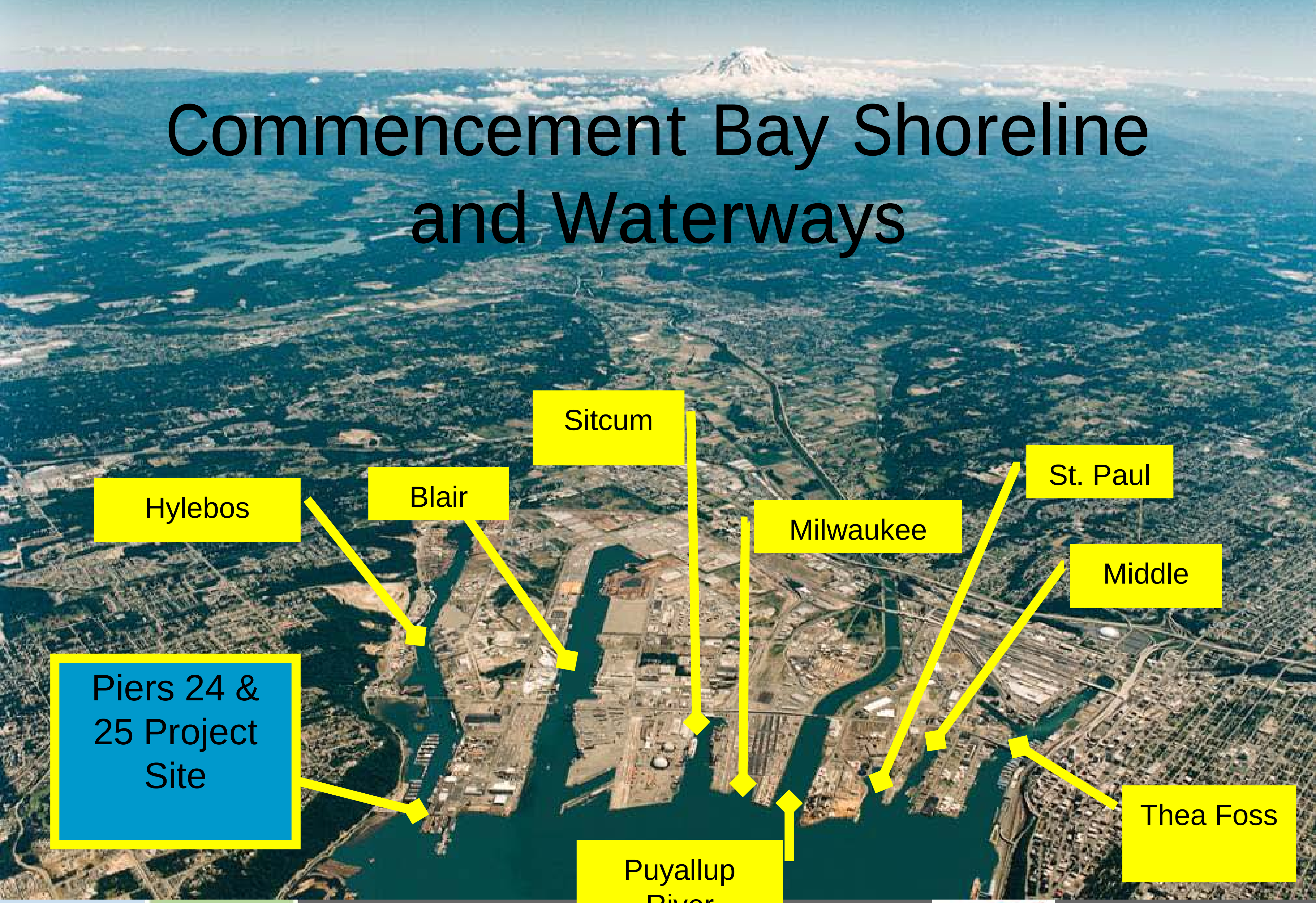
Port Priorities

- Minimize Impacts to Trident Seafoods
- Perform Pier Structural Repairs in Conjunction with Capping Work
- Complete Remedial Actions within the 2007 – 2008 Fish Window

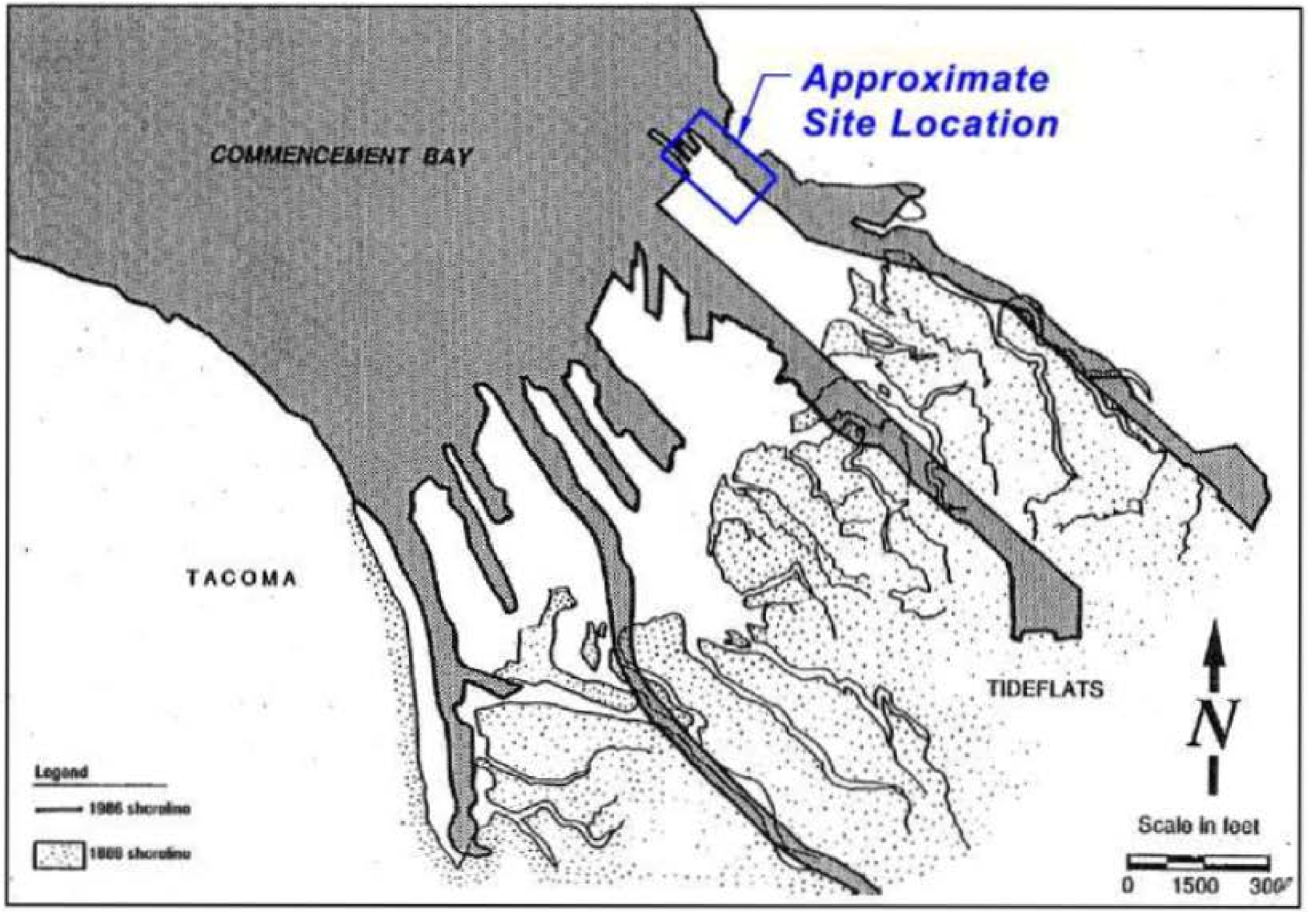
Acknowledgments

- US EPA
- US Army Corps of Engineers
- Washington State Department of Ecology
- Hart Crowser
- Bergerson Construction
- Berger/ABAM

Commencement Bay Shoreline and Waterways



Historical Tideflat Filling



Commencement Bay tideflats and shoreline modifications as of 1988, from *Commencement Bay Nearshore/Tideflats Record of Decision* (EPA, 1989)

Commencement Bay Federal Superfund Site

- Federal Register Listing in 1981
- EPA Created Seven Sub (Problem) Areas
- Port of Tacoma Located within the Nearshore /Tideflats Superfund Site Problem Area
- Hylebos Waterway One of Four Owned by the Port

Commencement Bay Federal Superfund Site

- Port of Tacoma Named a PLP in 1988
- UAO Signed in 2002, for the “Mouth of Hylebos Waterway” (Segments 3 – 5)
- CD Signed in 2005
- Piers 24 & 25 Capping Part of the Required Work in Segment 5

Nearshore/Tideflats Problem Area
Mouth of Hylebos Waterway

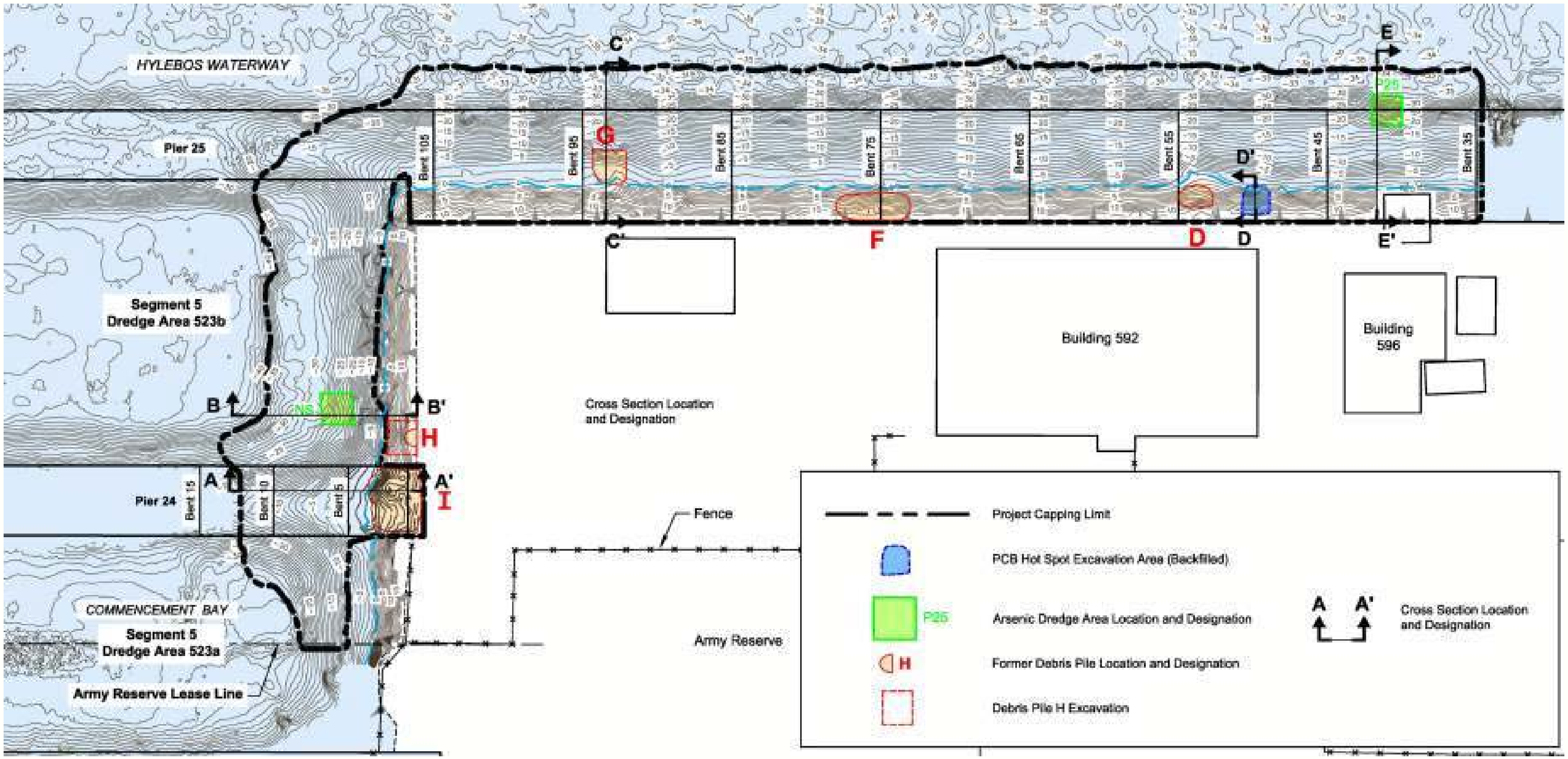
- $27.5M Port Costs to Date
- $12M in Reimbursements
- Net $15.5M Out of Pocket
- Spending within the Hylebos Waterway by all PLPs >$110M

Site Vicinity and Project Area

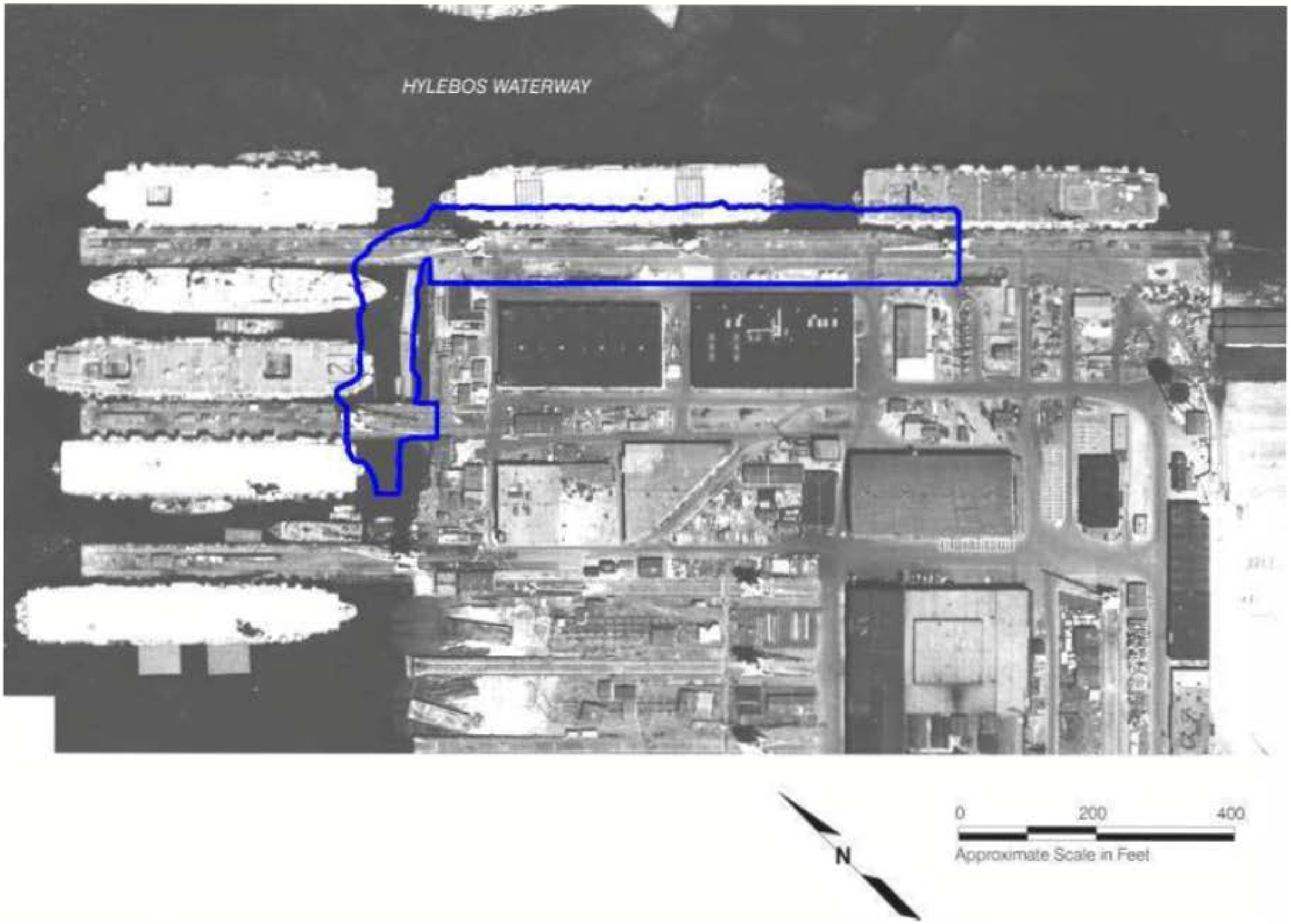
2006 Aerial Photo

Source: City of Tacoma

Piers 24 & 25 Project Area



1946 Aerial Photo



Site Contaminants

- Metals, PAHs, and PCB Contamination from Historical Shipyard Operations
- A Convenient Place to Dump Waste
- A Difficult Place to Clean Up

A Difficult Place to Work

- Limited Access
- Forest of Pilings
- Steep, Slippery Rock Slopes

Debris Pile Removal

PORT of TACOMA U.S.A.

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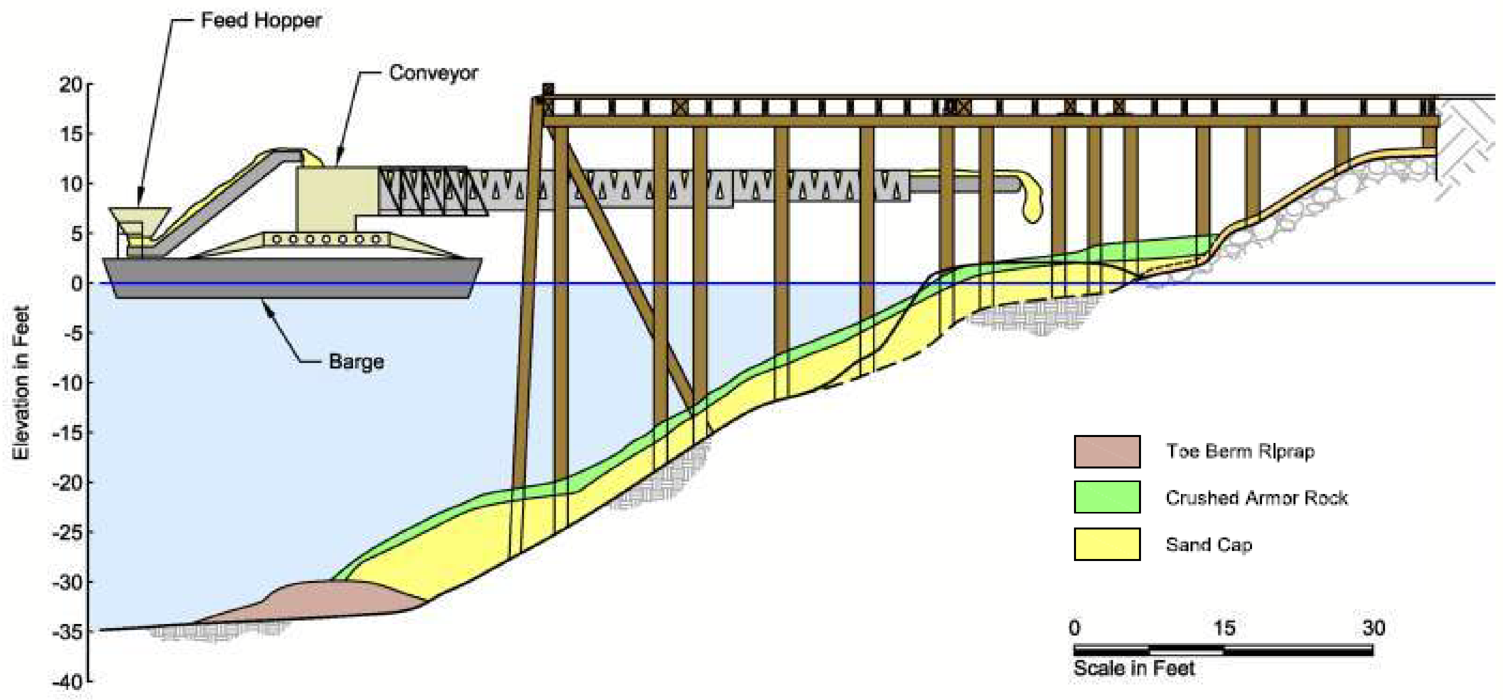
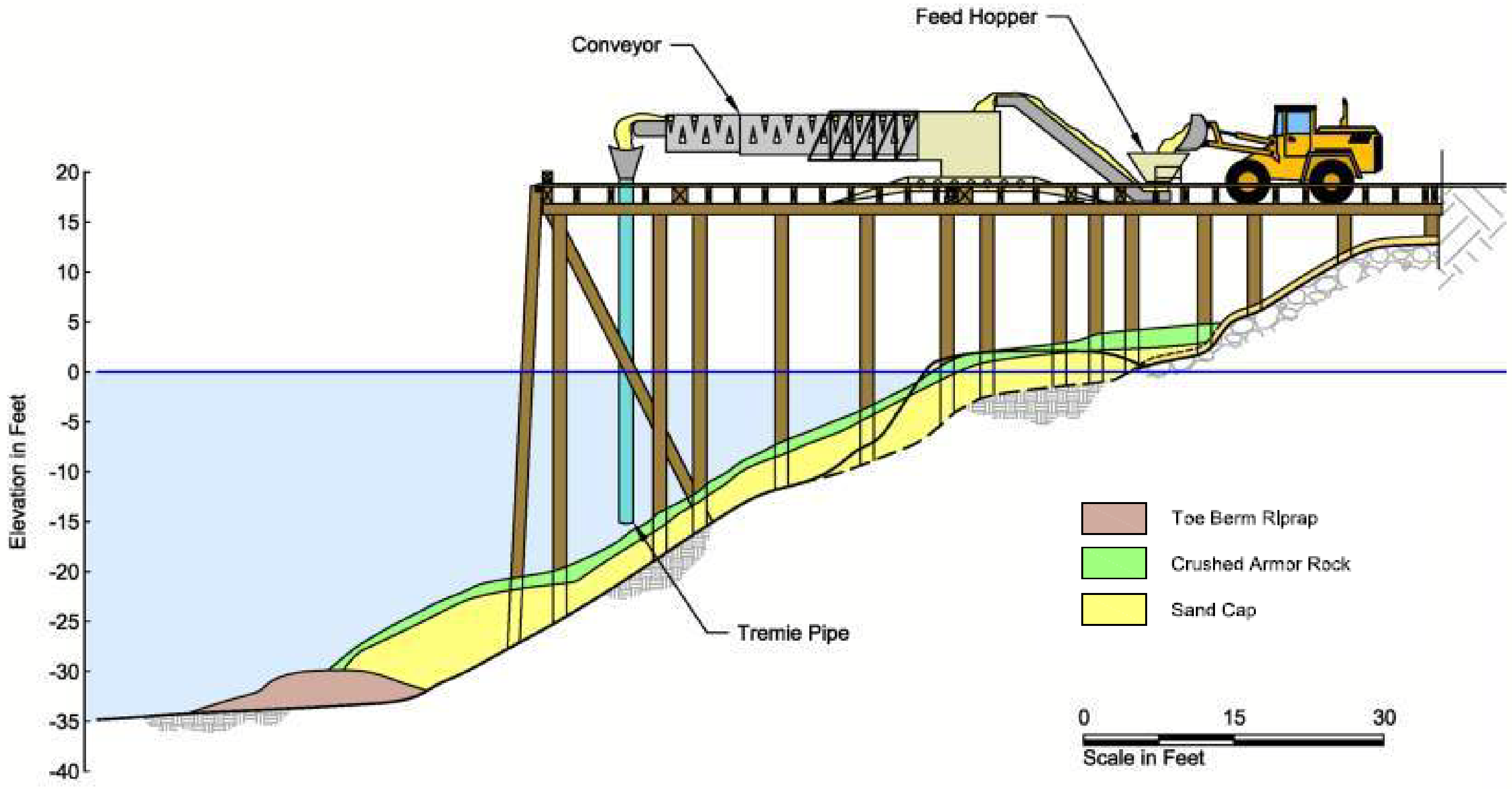
Initial Capping Design Concept – Barge-Staged Placement



Adapted Capping Concept – Pier-Staged Placement



Sand Cap and Armor Rock Placement

Sand Cap and Armor Rock Placement

Sand Cap and Armor Rock

Shotcrete Application

Shotcrete Application

PCB Hot Spot Removal

Lessons Learned – The Good

- Construction Methods Successful for Steep Slope Capping
  - Sand Cap 200 to 400 CY/Shift
  - Crushed Armor Rock 200 to 300 CY/Shift
  - Shotcrete 30 to 50 CY/Shift
- Total Construction Cost $4.8M
  - Within 1% of Engineering Estimate Excluding Change Orders

Lessons Learned – The Challenges

- PCB Hot Spot and Deeper Debris Excavation Were Unexpected and Costly
  - Difficult to Obtain Representative Sampling Data
- 50% Toe Berm Riprap Quantity Over-Run
  - Challenging to Estimate Angle of Repose and Settling

And The Long Term...

- Piers 24 & 25 Cap Performing as Designed

Armor Rock and Shotcrete – October 2010

Thanks to Battelle

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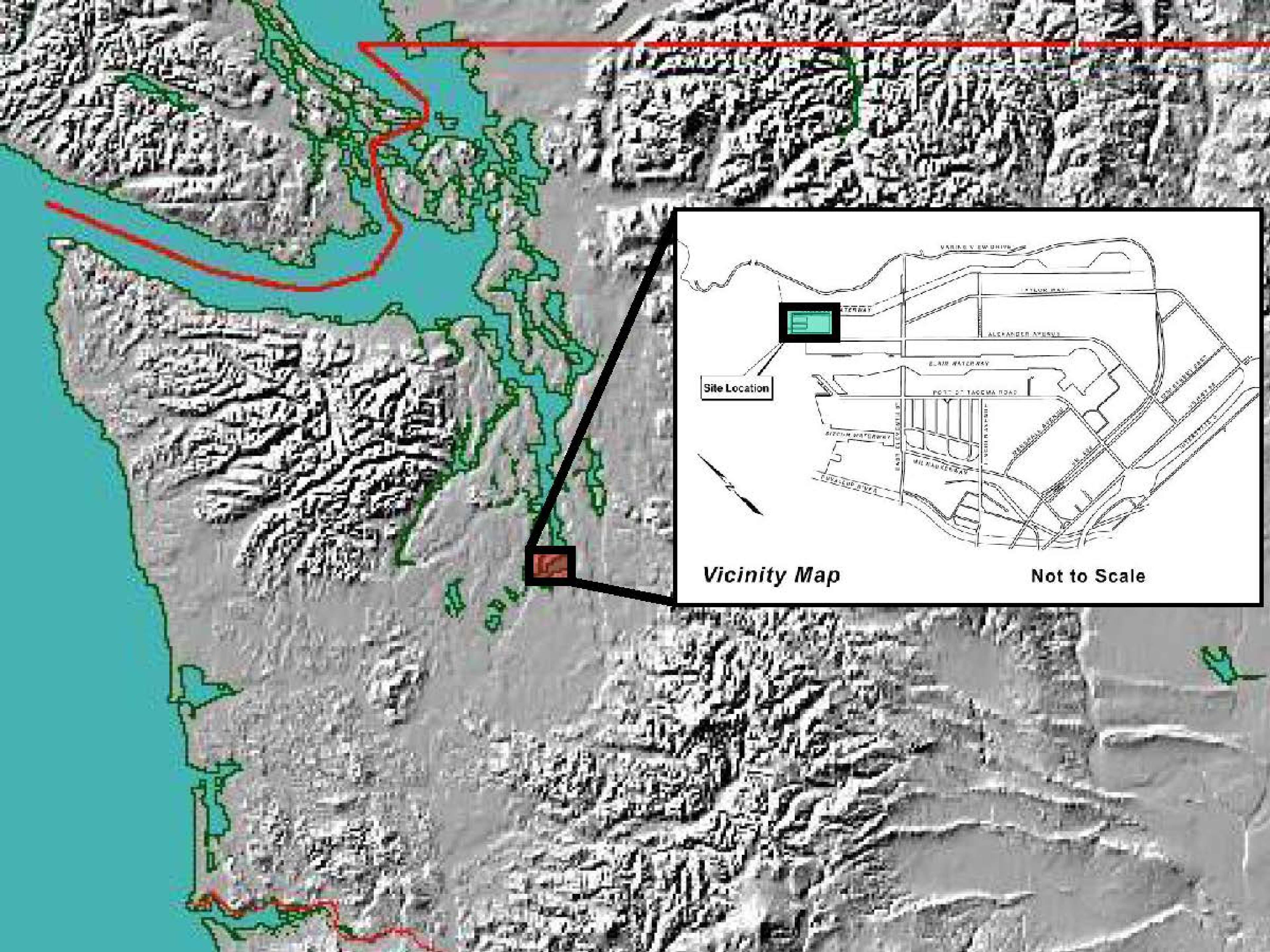


TAYLOR WAY
ALEXANDER AVENUE
BLAIR WATERWAY
PORT OF TACOMA ROAD
Site Location
Vicinity Map
Not to Scale

Design and Construction Timeline

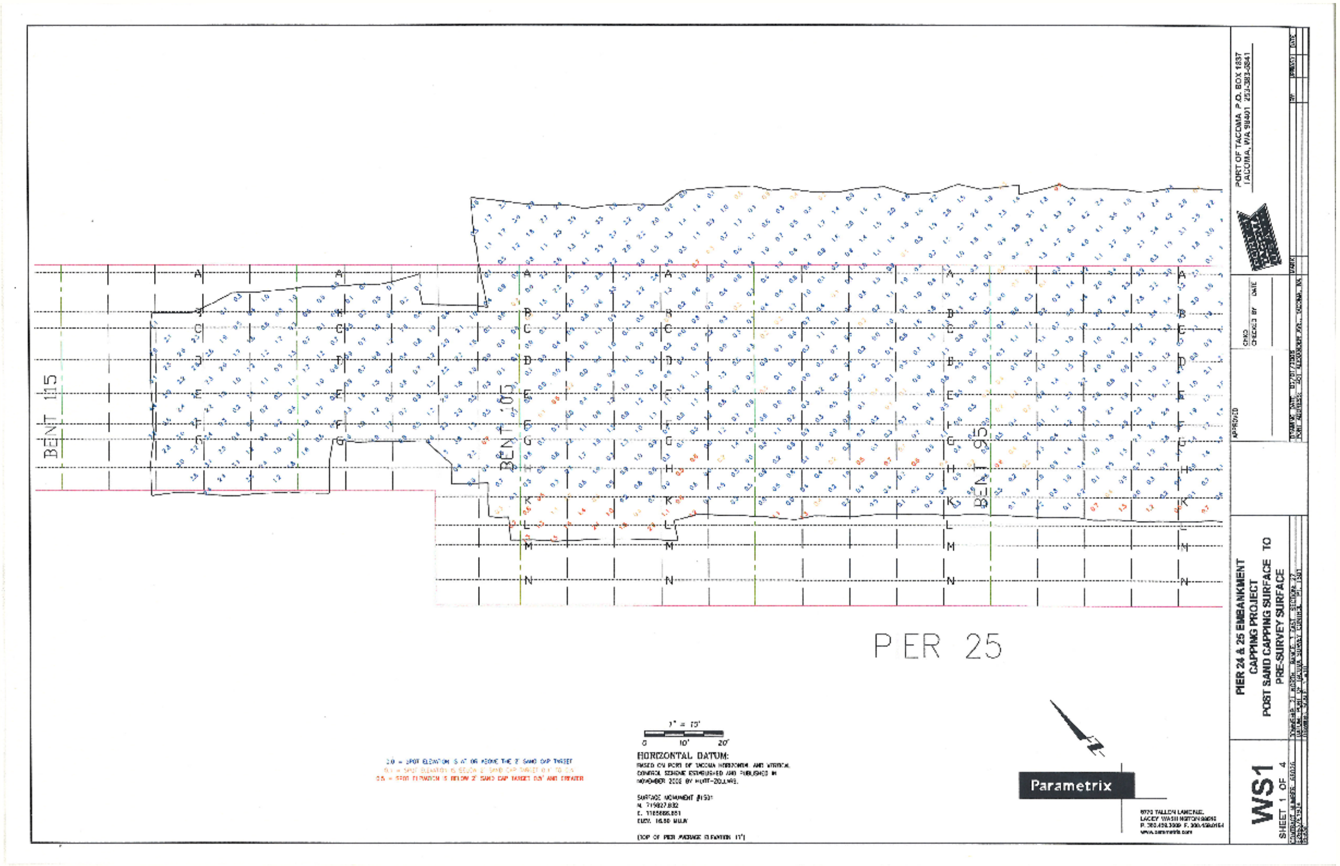
- 1998 to 2000 Remedial Design
- 2000 to 2007 Revise/Finalize Design
- 10/07 and 2/08 Complete Construction

Remediation Elements

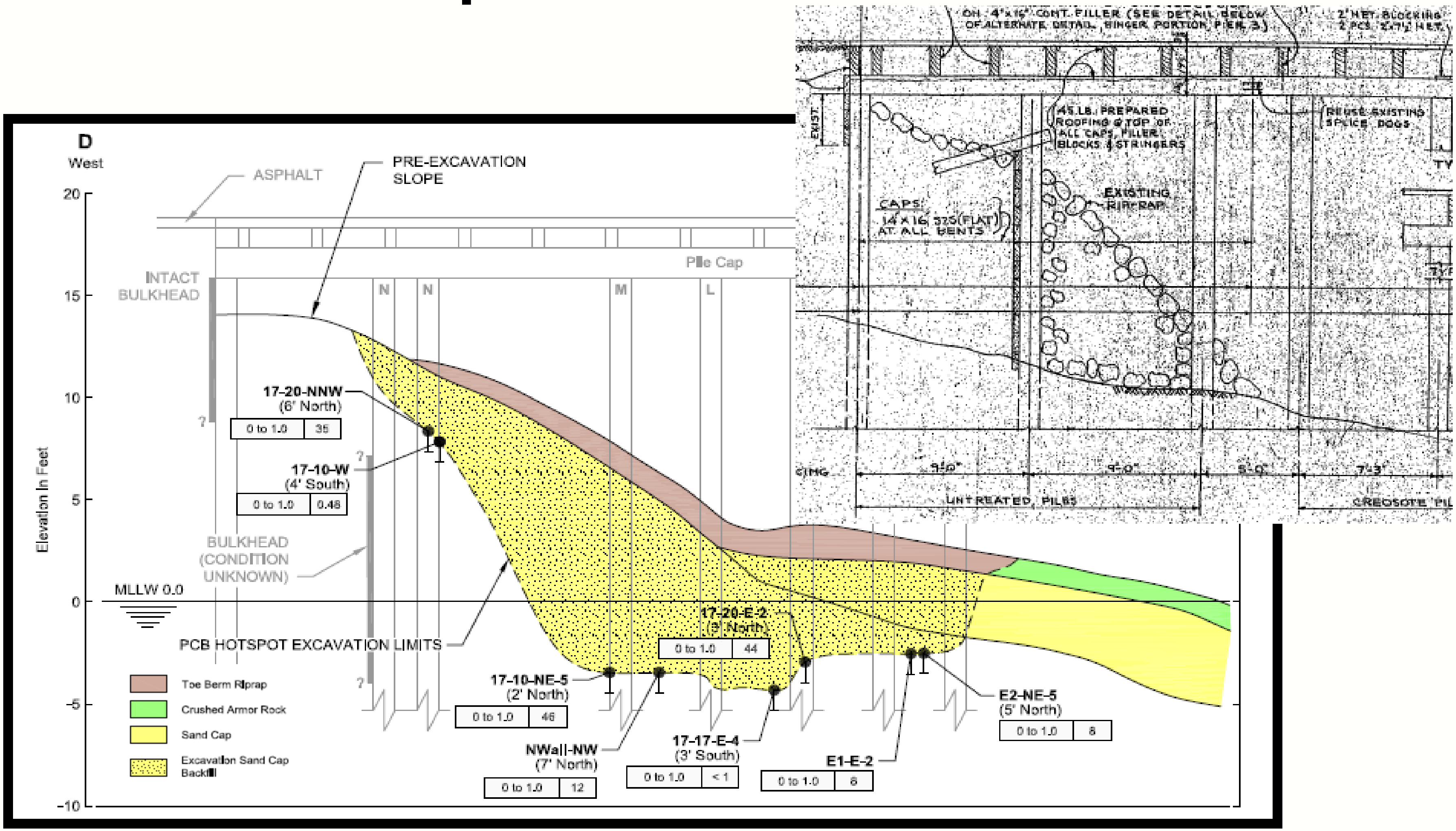
- Fused Metallic Debris Pile Removal
- Embankment Capping on 2V:1H Slopes
- Shotcrete Portions of Pier 25 Upper Bank With Elevated Contaminant Concentrations
- Hot Spot PCB Removal – Upper Bank
- Hot Spot Dredging for Arsenic

Toe Berm Riprap Placement

Lead Line Survey Control



PCB Hot Spot Removal



And The Long Term...

- Piers 24 & 25 Cap Performing as Designed

Armor Rock Cap Protection – October 2010